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NEST-SITE CHARACTERISTICS AND NESTING SUCCESS OF THE MALABAR GRAY HORNBILL IN THE SOUTHERN WESTERN GHATS, INDIA

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Abstract.—We quantified and characterized the nesting habitat of Malabar Gray Hornbills (*Tockus griseus*) Dec. 1993—May 1994 in the Anaimalai Hills of southern Western Ghats, India. Twenty-six nest-site variables were recorded in each of 27 nest plots to evaluate variability of nest-site selection. Malabar Gray Hornbills selected nest trees of significantly larger diameter at breast height (DBH 60–89 cm), and greater height of the lowest limb than the associated values from randomly chosen trees. The number of trees of 60–74 cm DBH class was significantly higher in the nest site plots than in the random plots. Most nests were in tall live trees and were formed primarily by heart rot where a branch had broken. Comparison of relative abundance of potential nest cavities and availability of trees in different DBH classes in belt transects indicates that more cavities were formed in trees of larger diameter. Density of potential nest cavities was 10/ha. Malabar Gray Hornbills consistently chose smaller trees than sympatric Great Hornbills (*Buceros bicornis*). This study indicates the need of mature moist forest habitat for nesting by the Malabar Gray Hornbill. *Received 13 Oct. 1995, accepted 14 Feb. 1996.*

The Malabar Gray Hornbill (*Tockus griseus* = *Ocyceros griseus*), the smallest of nine species of Indian hornbills, is endemic to the heavy rainfall tracts of the Western Ghats in southern India. It occurs commonly from Khandala in the north to the tip of the peninsula, from foothills to an altitude of about 1600 m above mean sea level (Ali and Ripley 1987). The preferred habitat of the species, moist deciduous and evergreen forest, has diminished and has become fragmented over much of the Western Ghats during the last century (Chattopadhyay 1985, Nair 1991). In the Anaimalai hill ranges of the Western Ghats, the Malabar Gray Hornbill occurs sympatrically with the largest Indian hornbill, the Great Hornbill (*Buceros bicornis*). These species are useful indicators of primary moist forest habitat.

Like other hornbills, the nesting female Malabar Gray Hornbill seals itself inside natural tree cavities until just before the fledging of the chick. Hornbills are secondary cavity nesters, i.e., they nest in large tree cavities naturally formed by decay or excavated by primary cavity nesters such as woodpeckers. They show high nest-site fidelity, returning to the same tree year after year (Kemp 1978). Many studies of Southeast Asian hornbills have stressed that they require extensive tracts of mature forest hab-

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itat with large, tall canopy trees for foraging and nesting (Kemp and Kemp 1975, Leighton 1982, Leighton and Leighton 1983, Johns 1987, Kannan 1994, Poonswad 1995). Cody (1985) suggested that the availability of suitable nest sites may play a major role in the population dynamics of cavity nesters. In this paper we describe the nesting habitat requirements of the Malabar Gray Hornbill by comparing nest-tree centered plots with random plots, thus identifying the factors influencing nest-site and nest-cavity selection. We also evaluate the nesting success of the species in the study area and compare nesting habitat requirements of the Malabar Gray Hornbill with that of the sympatric Great Hornbill.

STUDY AREA AND METHODS

The study was conducted in the Indira Gandhi Wildlife Sanctuary (approximately 10°25′N; 76°58′E) in Tamil Nadu state of India, which is spread over 1250 km^2 in the Anaimalai Hills of the southern Western Ghats. The altitude ranges from 315–2500 m. The Karian Shola National Park, where most of the observations were made, is a 5.1 km^2 patch of Southern Tropical Wet Evergreen Forest (Champion and Seth 1968) at an altitude of 750 m. This forest is surrounded by bamboo and open deciduous forests. The mean annual rainfall is 1400 mm, obtained from the southwest (June–Sept.) and the northeast (Oct.–Dec.) monsoons.

We made field observations from December 1993 to May 1994, during the breeding season of the Malabar Gray Hornbill (Ali and Ripley 1987). Hornbill nests were found by following parent birds and checking for piles of seeds and fecal matter (middens) at the base of nest trees. A tribal guide also showed us traditional nests. The habitat quantification methods followed James and Shugart (1970) with modifications to suit tropical forest conditions, and was similar to that of Kannan (1994) on the Great Hornbill, thus making the two data sets comparable. Ten vegetational parameters and nine nest cavity parameters were quantified in 15-m circular plots (0.07 ha) with the nest tree in the center. Vegetational parameters were also quantified in similar plots located at random 75 m from the nest tree to measure parameters in the general habitat. At the random points, the nearest tree ≥20 cm DBH was taken as center of the plot. Comparison of random plots with nest-tree plots were made to determine parameters likely to affect choice of nesting habitat by the Malabar Gray Hornbills. We used non-parametric Wilcoxon two-sample tests to determine significant differences ($P < 0.05$), using standard SPSS software (Norusis 1990, Table 1), as only three of the 10 vegetational parameters were distributed normally. Nest-cavity orientation was tested for nonrandomness using the goodness-of-fit of the Poisson distribution (Zar 1984). Twenty-seven nests were observed during this study. Each of the nests was examined at regular intervals to determine nesting status. Nesting was considered successful if at least one chick fledged or if the nest was found to be active at the termination of the study in May 1994. To determine the availability of potential nest cavities for the hornbill, five belt transects of 200 m × 100 m (i.e., total of 1 ha) were laid at random. All trees ≥30 cm DBH were carefully scanned, using 7 × 50 binoculars, for the presence of potential nest cavities (entrance diameter ≥ 6 cm). Classification of trees into DBH classes and other cavity parameters was the same as that used in the plots for nesting habitat quantification.

RESULTS

Nesting habitat characteristics.—Most of the nests were in open, tall (average height = 24 m), evergreen forest with dense undergrowth. Only

TABLE 1

MEASUREMENTS OF MALABAR GRAY HORNBILL NEST CAVITY PARAMETERS

Parameters	Mean	Standard error	N[a]
Diameter at nest height (cm)	42.4	2.1	26
Cavity width (cm)	8.3	0.3	27
Cavity length (cm)	8.4	0.3	27
Cavity height (m)	16.5	0.9	27
Distance to nearest branch (m)	1.8	0.2	27
Distance between cavity and canopy (m)	11.1	1.0	27

[a] Number of nest trees.

three parameters differed significantly between nest-site plots and random plots ($P < 0.01$; Table 2). These were DBH, the height of the lowest branch, and the number of trees of 60–74 cm DBH within the plot. The number of trees of 90–104 cm DBH also was higher in the nest plots ($P < 0.1$). Mean DBH of nest trees (75 cm) was larger than that of center trees of random plots (46 cm). The mean height of the first branch from the ground also was significantly higher in nest trees (16 m vs 11 m). Twenty-two (81%) of the 27 nests were on emergent trees, while only 13 (48%) of center trees of random plots were emergent, the mean emergence of nest plots being 4 m, 3.5 m higher than in the random plots. Similarly, while 21 of the nest trees were the tallest in the nest plots, only 6 of the center trees were the tallest in the random plots. However, the mean height of the tallest tree tended to be greater in the random plots. The DBH of the nest tree and its height were correlated ($r = 0.438$, $P = 0.02$), and the latter was in turn correlated to the height of the lowest limb ($r = 0.626$, $P < 0.001$). The foregoing variables reflect the Malabar Gray Hornbill's choice of large trees for nesting.

Since the frequency distributions of trees of various DBH classes in the nest-site plots and random plots were similar, the data were pooled for analysis. To examine whether hornbills were nesting selectively in trees of a particular DBH, the frequencies of nests in trees of predetermined DBH classes 20–39 cm, 40–59 cm, 60–79 cm, 80–99 cm, 100–119 cm, and >120 cm were compared with the pooled frequency of trees in these DBH classes. The nest tree DBH deviated significantly from random (Fig. 1, Kolmogorov-Smirnov two-sample test, $D = 16/27$, $P < 0.01$). Trees in the 60-89 cm range particularly appear to be preferred; 12 (44%) of the 27 nests were in such trees, although only 81 (19%) of the trees in the nest plots were in this range. Six (22%) of the nests were in trees of DBH >90 cm and nine (33%) in trees of the 30-59 cm range

TABLE 2

COMPARISON OF PARAMETERS IN MALABAR GRAY HORNBILL NEST-SITE PLOTS AND RANDOM PLOTS

Parameters	N	Nest plots[a]	Random plots[a]	Z	*P*
Shrub density/60 m^2	26	69.4 (5.2)	61.6 (6.0)	−1.18	0.238
Canopy cover %	26	85.2 (2.3)	83.6 (2.2)	−0.73	0.466
Ground cover %	26	28.9 (2.8)	38.3 (4.2)	−1.35	0.179
Mean canopy ht. (m)	27	23.9 (0.8)	24.7 (1.4)	−0.82	0.420
Tallest tree (m)	26	28.4 (1.4)	33.0 (1.7)	−1.71	0.087
Center tree ht. (m)	27	27.7 (1.4)	25.1 (1.4)	−1.28	0.201
Center tree DBH (cm)	27	75.3 (5.3)	45.7 (5.0)	−3.21	**0.001**
Distance to large tree (m)	26	7.1 (1.0)	8.2 (0.9)	−0.32	0.751
Lowest limb (m)	27	15.7 (0.9)	10.5 (1.1)	−3.77	**0.000**
Tree emergence (m)	27	3.8 (1.0)	0.3 (1.7)	−1.79	0.073
Number of trees					
15–29 cm DBH	27	7.5 (1.0)	9.5 (1.1)	−1.01	0.313
30–44 cm DBH	27	3.8 (0.4)	3.0 (0.4)	−1.26	0.206
45–59 cm DBH	27	1.8 (0.2)	2.3 (0.4)	−0.86	0.390
60–74 cm DBH	27	1.4 (0.2)	0.4 (0.1)	−3.11	**0.002**
75–89 cm DBH	27	0.5 (0.2)	0.3 (0.1)	−1.24	0.214
90–104 cm DBH	27	0.6 (0.1)	0.2 (0.1)	−1.73	0.083
≥105 cm DBH	27	0.5 (0.2)	0.6 (0.1)	−0.28	0.776

Differences were tested using Wilcoxon Signed 2-Sample Test for 2-tailed significance at $P < 0.1$ (Underlined) and $P < 0.01$ (Bold and underlined).

[a] Mean ± SE; N = Number of sample plots.

(Fig. 1). A comparison of the relative abundance of potential nest cavities and the availability of trees in different DBH classes in the belt transects indicates that more cavities are formed in trees of larger diameter (>60 cm).

Nest cavity characteristics.—Nest cavities were located at an average height of 16.5 m, and the average diameter of the nest entrance was about 8 cm. Mean diameter at nest height (DNH) was estimated to be 42 cm (N = 27). The cavity entrance was circular in 25 of 27 nests and oval in the other two. The mean width and length of the cavity entrance, distance of the cavity to the nearest branch, and distance between the cavity and canopy were also calculated (Table 1). All cavities except one were in live trees. Twenty-one (78%) of the nests were apparently formed as a result of heart rot where branches had broken off, while others were excavated by primary hole nesters. Sixteen (59%) of the nests were on the main trunk and the rest on branches. A majority (59%) of the nest cavities were located on the middle third of the tree, i.e., 9–18 m high,

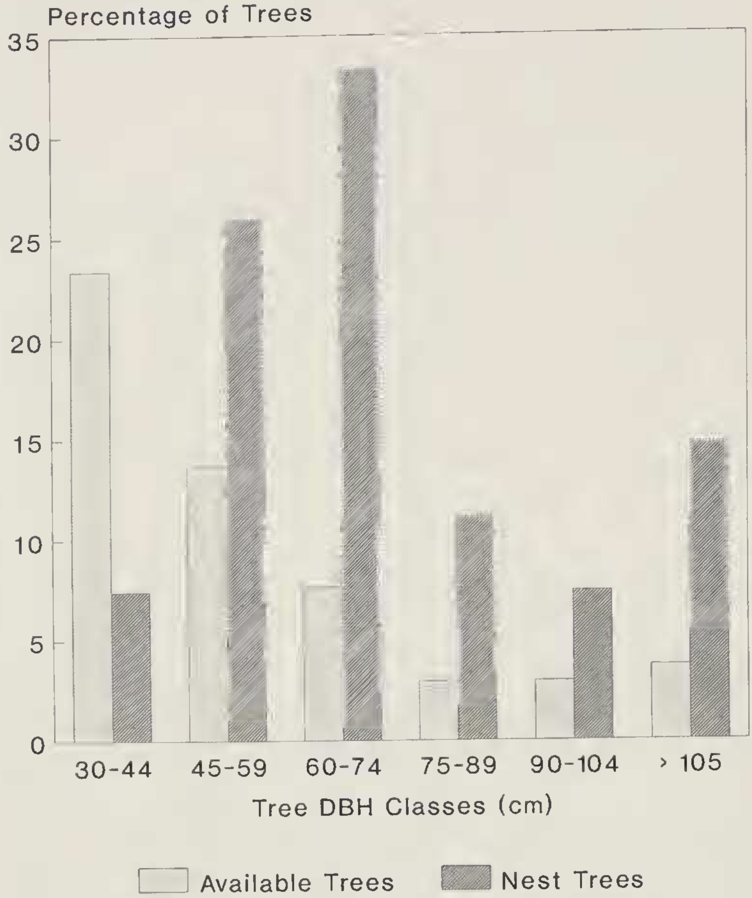

FIG. 1. Frequency distribution of DBH values of available trees and nest trees.

followed by 33% in the upper third (>18 m) and only 7% in the lower third (<9 m). There was a significant difference in the degree of orientation of the nest cavities (χ^2 = 12.14, df = 3, P = 0.01). A higher proportion of both the active and potential nest cavities in the limited sample available in the 1 ha area were oriented in the northeast direction (Figs. 2A and 2B).

Of 157 trees above 30 cm DBH in the 1-ha area sampled, only 10 had cavities potentially suitable for the Malabar Gray Hornbill. A comparison of the presence of nests and availability of nest cavities in trees of three different DBH classes (30–59 cm, 60–89 cm, and >90 cm) showed that hornbills were using trees of these DBH classes more or less according to their availability (χ^2 = 3.45, df = 2, P > 0.1). Three of the four tree species used most frequently for nesting occurred in the 1-ha plot that

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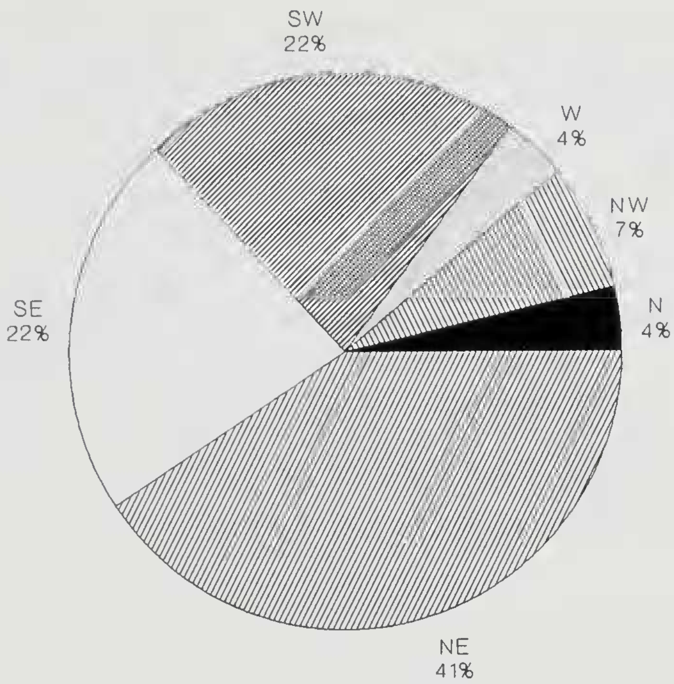
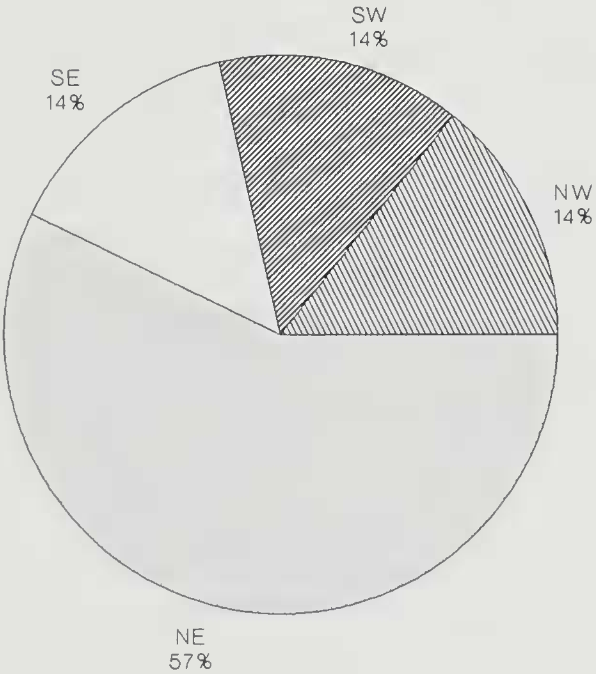
FIG. 2. (A) Orientation of nest cavities of Malabar Gray Hornbill nests (N = 27). (B) Orientation of potential nest cavities of the Malabar Gray Hornbill in one ha (N = 7).



A



B

was sampled (*Alseodaphne semecarpifolia, Hopea parviflora, Aglaia roxbhurghiana).* Seven of the 27 nests were in *A. semecarpifolia* trees.

Nest-cavity dimensions.—One nest of the Malabar Gray Hornbill which was at a height of 22.2 m was examined on 1 March 1994. The interior dimensions were 25 cm (width) × 36 cm (depth). The DNH of the tree was estimated to be 65 cm. The cavity extended into the interior of an adjoining branch forming a "funk hole" (i.e., an extension of the cavity into another branch or higher up into the bole) into which the incubating female withdrew. The measurement along this axis was 63 cm. The cavity had no particular inner lining although wood dust with some seeds were obtained. A single egg was present. The off-white, smooth, and slightly dirty egg measured 4.5 × 3.5 cm. On 5 March, the female resealed the cavity. By 22 March, the chick had hatched and egg shells were found in the midden.

Nesting success.—Of the 27 nests monitored, 14 successfully fledged young and 10 were active at the end of the study period. Of the remaining three nests, one was abandoned in mid April 1994, one could not be observed due to poor visibility, and the other was not used in 1994 for nesting (this nest was active during the preliminary survey in May 1993). Overall, 24 (88.9%) of the 27 nests were considered successful.

DISCUSSION

Cavities are an important resource in forests for many birds and mammals which use them for nesting, roosting, and escaping from predators. To a certain extent, the choice of cavities may also depend on the faunal community, especially in terms of avoiding interspecific competition for nest sites and food (Kalina 1988, Li and Martin 1991, Conway and Martin 1993), predation (Kemp 1976, Cody 1985, Martin 1988), and presence of adequate foraging habitat (Conner 1976). However, nest-tree and nest-cavity factors may be the most important primary factors influencing nest habitat choice in hornbills (Kannan 1994).

Nest-site selection.—Nests of the Malabar Gray Hornbill were found in open, tall evergreen forest along forest trails, edges and interior areas. The data obtained reflect size and age of nest trees and indicate that hornbills prefer mature forest stands. Although most of the nest cavities were in emergent trees, they were not necessarily the tallest trees in the habitat. The Malabar Gray Hornbill uses relatively smaller trees than the sympatric and much larger Great Hornbill which was found to prefer nests in trees that were larger in terms of mean height (43.8 m), emergence (12.8 m), DBH (133 cm), and DNH (79 cm) (Kannan 1994). It is, therefore, evident that there is little overlap in nesting habitat choice between the two sympatric hornbills in the study area.

Relatively more nests were found in trees of larger DBH classes, particularly in the 60-89 cm range. This cannot be taken to indicate the preference of the hornbills, as it may simply reflect the greater availability of suitable cavities in larger trees. A large number of nests (26) were in live trees. The potential nest cavities located in the 1-ha plot were also in live trees. Selective logging of trees is usually directed towards the extraction of large rain forest species for timber and prioritizes removal of trees with cavities, heart rot, and strangler species (*Ficus*) as unwanted during silvicultural operations. Such activities continue in many areas in the Western Ghats, even within protected areas. These trees are essential for the Malabar Gray Hornbill as potential nesting sites. Large fruiting trees were also shown to be an important component of hornbill habitat (Kannan 1994). Therefore, this is a consideration that should be incorporated in traditional forestry practices.

Nest-cavity characteristics.—The nests of the Malabar Gray Hornbill were located at substantial heights in evergreen forest trees. Height at which the nest is located may simply reflect the fact that nest cavities are formed more frequently in the higher reaches of the tree. The propensity of the hornbill to choose cavities with small entrances is supported by observations on conspecifics in Africa (Kemp 1976, 1978). One nest, active in 1993 but abandoned the following year, had a cavity entrance diameter of 15 cm, suggesting that tree growth could have enlarged the cavity, thereby rendering it unsuitable for nesting. Many hornbills were seen assiduously enlarging the nest cavity entrance by removing overgrown wood tissue and debris. "Funk-holes" of the type discovered in this study have been reported by Kemp (1978) for most hornbills in the African and Oriental regions.

Nesting success.—Higher nests suffer lower amounts of predation in both primary and secondary cavity nesters (Li and Martin 1991). In hornbills, further protection is afforded by the sealed nest cavity entrance and the presence of the confined female. The low incidence of predation and the presence of suitable nesting habitat probably accounted for the high nesting success noted in this study. In general, nesting success in hornbills is probably one of the highest among hole nesters, by virtue of their unique nesting behavior. The importance of preserving cavities in large trees for hornbills is evident from this as well as several other studies (Leighton 1982, Ali and Ripley 1987, Kannan 1994).

Hornbills play an important role in forest dynamics because they disperse seeds of many forest trees, especially the large seeded ones (McKey 1975, Leighton and Leighton 1983), and may serve as "mobile links" (Gilbert 1980) in the food-web organization of rainforests (Kannan 1994). Loss of habitat due to conversion of primary forests into plantations and monocultures, especially of exotics such as *Tectona grandis, Eucalyptus,* and *Acacia* may adversely affect survival of these large forest birds. Thus, the conservation of hornbills assumes greater importance in preserving the entire threatened ecosystem of the Western Ghats.

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